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NAVAL RESEARCH LAB
HIGH VOLTAGE, HIGH
JAN 61 W M LAWSON
NRL-MR-1133

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POWER TRANSISTORS. CHARACTERISTICS OF DEVELO--ETC(U)

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MEMORANDUM REPORT 1133 ✓

6 HIGH VOLTAGE, HIGH POWER TRANSISTORS -
Characteristics of Developmental Units - 1

9 Interim Report ^{no.} Number 7

10 by Wilmer M. Lawson, Jr

11 5 January 1961

12 17p.

14 NRL-MR-1133

Electrical Applications Branch
Sound Division
U. S. NAVAL RESEARCH LABORATORY
Washington 25, D. C.

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ABSTRACT

↘ A group of ten samples of 300 volt, 10 and 25 ampere, silicon-power transistors manufactured by Westinghouse Electric Corporation has been received by the U. S. Naval Research Laboratory for evaluation. The units have been tested for breakdown, output- and saturation-voltage characteristics, and tabular and photographic data are presented.

Breakdown voltages of the semiconductor device itself were of the order of 400 volts on the four samples which were enclosed in the latest case design. However, the voltage is limited by the manufacturer to 300 volts, apparently from effects other than punch-through or similar semiconductor breakdown. Except for the four in the final case, design breakdown was usually unstable or a negative-resistance type. ↘ Output characteristics, current gain and saturation-voltage are satisfactory. ↗

PROBLEM AUTHORIZATION

ONR RF-001-03-41-4062, BUSHIPS 8134
NRL Problem Number 55S02-10

PROBLEM STATUS

This is an interim report on one phase of the project; work on this problem is continuing.

INTRODUCTION

The Semiconductor Division of the Westinghouse Electric Corporation has been pursuing a development program in the field of high power transistors leading to the production of 200 volt, ten ampere, 250 watt silicon units, labelled WX 115. Further work by the company has led to the production of some 300 volt, ten ampere, 300 watt silicon units. Ten sample transistors have been submitted by the company to NRL for testing. Of these, six are in an interim case, and four are in a final case design.

The results of static tests of breakdown, output and saturation voltage characteristics of these units are presented. Tests with these units in a class B amplifier are yet to be performed.

BACKGROUND AND TEST PROCEDURES

The static characteristics which are obtained at NRL are the breakdown voltage characteristics V_{cbo} , V_{ces} and V_{ceo} , the collector-output characteristic and the saturation-voltage characteristic.

Voltage-breakdown characteristics are taken using a curve tracer described in NRL Memorandum Report 1098, High Voltage, High Power Transistors, Characteristics of Developmental Units, Report 5.

Basically, a half-wave, sixty-cycle, sine-wave voltage is applied in series with a current-limiting resistor and a current shunt to the proper transistor terminals for the characteristic being taken. The voltage and current are displayed on the calibrated x and y axes of an oscilloscope.

The collector-output characteristics are taken with the aid of the dual-transistor characteristic-curve tracer described in NRL Memorandum Report 834, and a calibrated oscilloscope. From the photographs of the output curves, the output impedance and forward current, gain may be calculated. Saturation-voltage characteristics are taken with the curve tracer circuit of figure 1. Basically, the tracer applies a low-voltage, one-half wave, rectified sixty cycles per second sine-wave signal to the collector-emitter terminals of the transistor under test slightly after a large, fixed, dc bias current is applied to the base-emitter terminals.

The accuracy of these measurements is limited by the accuracy with which the data can be read from the photographs. Thus, values of

breakdown voltage, gain and saturation voltage quoted in this report cannot be compared rigorously to the data given by the manufacturer, but a good general description of the characteristics of the transistor is obtained.

TEST RESULTS AND DISCUSSION

The results of the voltage-breakdown tests on the individual units are presented in figures 2 through 11 and in numerical form in table I. The manufacturer's data on the units is included as table II. It may be seen that all of the units in the final case, taken from production, have breakdown voltages equal to or greater than 300 volts, with the exception of unit 107-5 which begins to break down in open base at 270 to 280 volts. The earlier units not only had breakdown voltages of less than 300 volts, but many exhibited negative-resistance breakdowns and instabilities. The manufacturer places a 300 volt absolute limit on collector voltage because of possible arc at the surface at lead clearances.

The output characteristics of the ten units are given in figures 12 to 21 and table I for a maximum base-bias of 100 milliamperes, a collector supply of 50 to 60 volts peak, and a 150 watt, peak-power dissipation. No heat sink was used. The current gain of the four units in the final case averaged about twenty at two ampere collector current and ten volt collector-to-emitter.

The saturation voltage characteristics for a 2.5 volt base-to-emitter bias are given in figures 22 to 31, and are generally less than the manufacturer's specification.

SUMMARY AND CONCLUSIONS

1. The breakdown voltage characteristics, figures 2 to 11, are generally equal to or greater than the manufacturer's 300 volt rating, particularly in later units. However, the manufacturer will not allow greater than 300 volts collector-to-emitter because of problems apparently associated with the fused structure.
2. Except in the last four units received, instability and negative resistance regions are exhibited at breakdown; the last four transistors do not show these effects, which may have been eliminated.

3. The output characteristics are generally satisfactory, with good, sharp corners and relatively even spacing.

4. The newer transistors have more gain, and although no data is supplied by the manufacturer, it is assumed that these are supposed to be 25 ampere units.

5. The saturation voltage of 0.2 to 0.8 volts at ten amperes is satisfactory.

TABLE I
SUMMARY OF CHARACTERISTICS OF
WESTINGHOUSE SILICON POWER TRANSISTORS
AS MEASURED BY THE U. S. N. S. RESEARCH LABORATORY

Transistor Number	$BV_{cbo}(v)$ $I_C = 0.5ma$	$BV_{ces}(v)$ $I_C = 1.0ma$	$BV_{ceo}(v)$ $I_C = 2ma$	h_{FE} $I_C = 2a, V_{ce} = 10v$	$SAT V^{(3)}(v)$ $I_C = 10a$	$SAT V(v)$ $I_C = 20a$
336-9	405	310 ⁽²⁾	300 ⁽²⁾	26	0.50	-
367-5	305	270	260	17 at 1.7a	0.80	-
367-4	>370	390	360	12.5 at 1.25a	0.80	-
367-11	>370	320 ⁽²⁾	320 ⁽²⁾	15 at 1.5 a	0.60	-
370-5	>370	250	250 ⁽²⁾	20	0.20	0.55
374-12	>370	315	285	25	0.40	0.70
107, #5 ⁽¹⁾	325	345	300	19	0.30	0.60
107, #6 ⁽¹⁾	>370	>370	>370	18	0.50	0.70
179, #3 ⁽¹⁾	>370	>340	380	19	0.20	0.60
179, #4 ⁽¹⁾	>370	>370	370	18	0.45	0.65

NOTES:

- (1) Final case design
- (2) Negative resistance breakdown
- (3) Taken with 2.5 volt base supply with no series resistance

TABLE II

MANUFACTURER'S CHARACTERISTICS
WESTINGHOUSE SILICON POWER TRANSISTOR (400 watts)

Transistor Number	$BV_{cbo}^{(2)}$ $I_C = 0.5\text{ma}$	$BV_{ces}^{(2)}$ $I_C = 1.0\text{ma}$	$BV_{ceo}^{(v)}$ $I_C \leq 10\text{ma}$	h_{FE} $I_C 10\text{a}, V_{ce} = 4\text{v}$	$SAT V^{(3)}_{(v)}$ $I_C = 10\text{a}$	$SAT V^{(v)}$ $I_C = 20\text{a}$	$Max I_C (a)$	$F_{cE} (kc)$
336-9	-	-	>300	12.5	0.70	-	30	19.5
367-5	-	-	>300	11.5	0.90	-	30	25.0
367-4	-	-	>300	10.0	0.85	-	30	25.0
367-11	-	-	>300	10.8	1.50	-	30	25.0
370-5	-	-	>300	10.5 at 20a	-	1.1	30	15.0
374-12	-	-	>300	30.0 at 25a	-	? 288v at 25a	30	15.0
107, #5 ⁽¹⁾	-	-	310	10.5	0.65	-	-	-
107, #6 ⁽¹⁾	-	-	350/2	10.5	0.55	-	-	-
179, #3 ⁽¹⁾	-	-	370/2	9.1	0.55	-	-	-
179, #4 ⁽¹⁾	-	-	370/2	9.5	0.60	-	-	-

NOTES:

(1) Final case design

(2) Manufacturer limits collector-to-emitter voltage to 300 volts



Fig. 2 - #336-9 (BV)

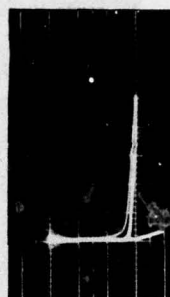


Fig. 3 - #367-5 (BV)

Hor. 100v/div.
 Vert. V_{cbo} - 5 ma/div. to 5 ma
 V_{ces} - 20 ma/div. to 60 ma
 V_{ceo} - 20 ma/div. to 100 ma

Hor. 100v/div.
 Vert. V_{cbo} - 5 ma/div. to 2 ma
 V_{ces} - 20 ma/div. to 60 ma
 V_{ceo} - 20 ma/div. to 100 ma



Fig. 4 - #367-4 (BV)

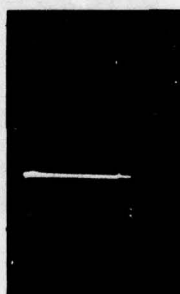


Fig. 5 - #367-11 (BV)



Fig. 6 - #370-5 (BV)

Hor. - 100v/div.
 Vert. - 2 ma/div.

Hor. - 100v/div.
 Vert. - 2 ma/div.

Hor. - 100v/div.
 Vert. - 2 ma/div.

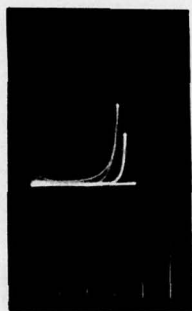


Fig. 7 - #374-12 (BV)

Hor. - 100v/div.
Vert. - 2 ma/div.



Fig. 8 - 107, #3 (BV)

Hor. - 100v/div.
Vert. - 2 ma/div.

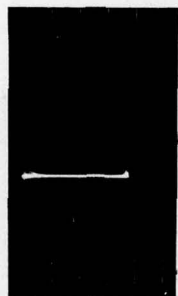


Fig. 9 - 107, #6 (BV)

Hor. - 100v/div.
Vert. - 2 ma/div.



Fig. 10 - 179, #3 (BV)

Hor. - 100v/div.
Vert. - 2 ma/div.



Fig. 11 - 179, #4 (BV)

Hor. - 100v/div.
Vert. - 2 ma/div.

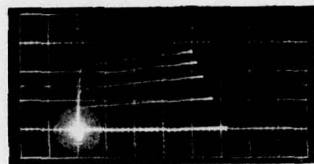


Fig. 12 - #336-9 (output)

Hor. - 10v/div.
 Vert. - 1A/div.
 Bias - 0, 25, 50, 75, 100 ma

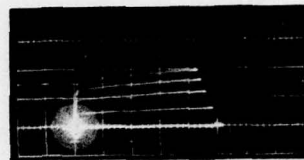


Fig. 13 - #367-5 (output)

Hor. - 10v/div.
 Vert. - 1A/div.
 Bias - 0, 25, 50, 75, 100 ma

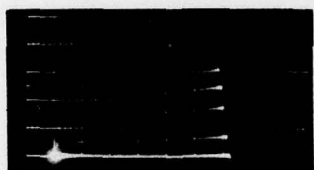


Fig. 14 - #367-4 (output)

Hor. - 10v/div.
 Vert. 1/2A/div.
 Bias - 0, 25, 50, 75, 100

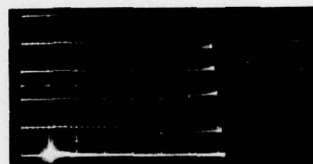


Fig. 15 - #367-11 (output)

Hor. - 10v/div.
 Vert. - 1/2A/div.
 Bias - 0, 25, 50, 75, 100

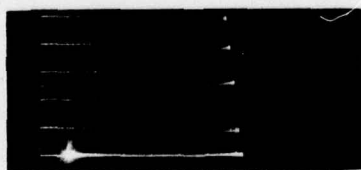


Fig. 16 - #370-5 (output)

Hor. - 10v/div.
 Vert. - 1/2A/div.
 Bias - 0, 25, 50, 75, 100

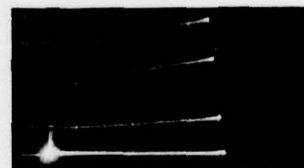


Fig. 17 - #374-12 (output)

Hor. - 10v/div.
 Vert. - 1/2A/div.
 Bias - 0, 25, 50, 75, 100

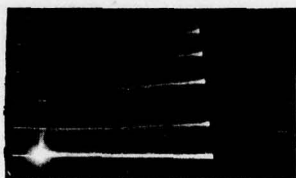


Fig. 18 - #107-5 (output)

Hor. - 10v/div.
 Vert. - 1/2A/div.
 Bias - 0, 25, 50, 75 100

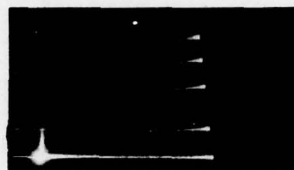


Fig. 19 - #107-6 (output)

Hor. - 10v/div.
 Vert. - 1/2A/div.
 Bias - 0, 25, 50, 75, 100

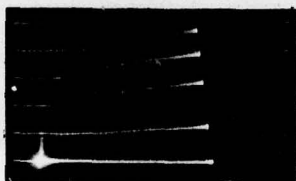


Fig. 20 - #179-3 (output)

Hor. - 10v/div.
 Vert. - 1/2A/div.
 Bias - 0, 25, 50, 75, 100

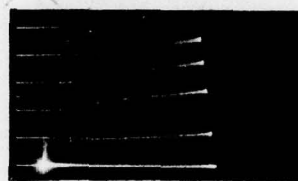


Fig. 21 - #179-4 (output)

Hor. - 10v/div.
 Vert. - 1/2A/div.
 Bias - 0, 25, 50, 75, 100

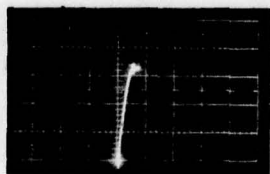


Fig. 22 - (Vsat) #336-9

Hor. - 2v/div.
 Vert. - 5A/div.



Fig. 23 - (Vsat) #367-5

Hor. - 2v/div.
 Vert. - 5A/div.



Fig. 24 - (Vsat) #367-4

Hor. - 2v/div.
Vert. - 5A/div.



Fig. 25 - (Vsat) #367-11

Hor. - 2v/div.
Vert. - 5A/div.



Fig. 26 - (Vsat) #370-5

Hor. - 2v/div.
Vert. - 5A/div.



Fig. 27 - (Vsat) #374-12

Hor. - 2v/div.
Vert. - 5A/div.

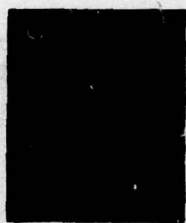


Fig. 28 - (Vsat) #107-5

Hor. 2v/div.
Vert. - 5A/div.



Fig. 29 (Vsat) #107-6

Hor. - 2v/div.
Vert. - 5A/div.

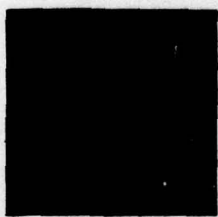


Fig. 30 - (Vsat) #179-3

Hor. - 2v/div.
Vert. - 5A/div.



Fig. 31 - (Vsat) #179-4

Hor. - 2v/div.
Vert. - 5A/div.